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Importance of Federal Motor Vehicle Safety Standards 207/210 in Occupant Safety - A Case Study

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Abstract

The purposes of this paper are twofold First, to understand the importance of Federal Motor Vehicle Safety Standards 207/210 in occupant safety and second to enhance strength of driver seat failure components In an effort to create safety guidelines for the vehicles driver seat the Federal Motor Safety Standards 207/210 are applies. These regulations are to ensure their proper location for effective occupant restraint and it also in order to minimize the possibility of anchorage failure due to the forces resulting from vehicles crash. Case study shows, Driver seat model is taken from the National Crash Analysis Centre(NCAC) web is modeled and analyzed using Hypermesh and LS Dyna software's respectively as per standards recommendations. From the baseline results it is observed that failure in seat tracks as failure strain produced 46%is higher than allowable strain 16.5%. Other components are concern. For track providing additional locking J-bracket is may be feasible solution. The theoretical discussion and result failure strain produced strain 11% is less than allowable strain 16.5% in this study can be applied in the driver's car seat design and construction to ensure occupant safety.

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Keywords: Occupant Safety, FMVSS 207/210, Toyota Yaris Driver Seat, FEA, Hypermesh, Ls-dyna.

Nomenclature

ϵ	Strain
F	Load in kN
ω	Frequency in Hz
T	Thickness in mm

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1. Introduction

The first motor vehicle fatality occurred in 1889 in New York City. Arguably this event led to the birth of automotive safety as a field of study. Over the past century, occupant safety has become an important design objective among all the performance criteria of ground transportation vehicles. Manufacturers realized early on the need to demonstrate occupant protection before the public accepted the automobile as a viable means of transportation. There are three distinct periods in the development history of automotive safety. [1]

Comfort is an attribute that today's consumers demand more and more. The seat has an important role to play in fulfilling these comfort expectations. Seating comfort is a major concern for drivers and other members of the work force who are exposed to extended periods of sitting and its associated side effects. Drivers of commercial vehicles are required to drive long and sometimes irregular hours. The personal vehicles are emphasizing factors such as ride comfort; handling, technology and appearance are of high importance in vehicle market. Diversions of requirements for commercial trucks and personal automobiles have led to separate directions particularly in seat design improvements had emphasized bolster design to increase stability, and adjustments for backrest angle, contouring, and seat height to promote good posture.[2] Most of the research findings concerning industrial and office chair design can be applied to auto seat design. However, there are several important considerations which are unique to the mobile environment that should influence design recommendations. [3]

2. Automotive Driver Seat Standards

Most of the standards in USA are FMVSS(Federal Motor Vehicle Safety Standards) regulations and ECE(Economic Commission of Europe) regulations in Europe. In our country now ARAI testing standards(AIS).

FMVSS standards can be obtained free of cost from the website and there are three 3 series listed in the Volume 49 Code for Federal Regulations. The 100 series deals with active safety or crash avoidance and 200 series forms the most important aspects of crashworthiness tests. Listed in series 200 are several standards an attempt has been made to give the reader a brief study of them. One can refer to the information available online on NCAP (New Car Assessment Program), IIHS (Insurance Institute for Highway Safety) and NHTSA(National Highway Traffic Safety Association).[7]

NHTSA's head restraint standard in order to reduce whiplash injuries in collisions. For front distance between the back of an occupant's head and the occupant's head restraint, as well as a limit on the size of gaps and openings within head restraints. The rule also establishes new strength and dynamic compliance requirements, and amends most existing test procedures. [8]

2.1 Federal Motor Vehicle Safety Standard 202(FMVSS202)

Head Restrain-

First establish the displaced torso reference line by applying a rearward moment of 373Nm about the R-Point, perpendicular to the design torso line, to the top of the back frame. Then apply a rearward moment of 373 Nm about the H-Point, perpendicular to the displaced torso line, 64mm below the top of the head restraint. Now increase the load to 890 N or failure, whichever occurs first.

The maximum displacement of the headrest, measured perpendicular to the displaced torso line, should be no more than 102mm, for the load. Furthermore there should be no failure at this load.

2.2 Federal Motor Vehicle Safety Standard 208(FMVSS208)

Occupant Crash Protection-Frontal Impact-

Impact a vehicle with seated test dummy 50th percentile male hybrid III dummy in the front driver seat, travelling longitudinally forward at 30 mph, into a fixed collision barrier that is normal to the line of travel. The time interval prescribed in FMVSS 208 is 36 msec. acceleration a is measured at the head centre of gravity in terms of g units. The resultant acceleration, measured at the centre of gravity of the upper thorax, should not exceed 60g, except for intervals whose cumulative duration is not more than 3 sec. [7]

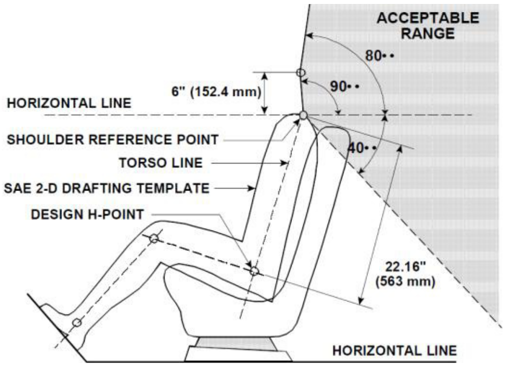

Fig.1 Seat Type 1 or Type 2 Seat Belt Anchorages.

2.3 Federal Motor Vehicle Safety Standard 207(FMVSS207)

FMVSS207 is for Seating Systems — Passenger Cars, Multipurpose Passenger Vehicles (MPVs), Trucks and Buses.

2.3.1 General

Seats should remain in its adjusted position during the application of each force. Seats that fold should be equipped with a self locking device for restraining the seat or seat back. If there any Designated Seating Position (DSP) behind the seat which require the restraining device to be operated to exit from the vehicle, it should be easily accessible.

2.3.2 Purpose And Scope

This standard establishes requirements for seats, their attachment assemblies, and their installation to minimize the possibility of their failure by forces acting on them as a result of vehicle impact.

2.3.3 Definition

A seat that provides at least one designated seating position (DSP).

2.3.4 Analysis

In all adjustable positions, a force equal to 20 times the weight of the seat, in the forward longitudinal direction, applied through the seat centre of gravity by a suitable rigid fixture. In all adjustable positions, a force equal to 20 times the weight of the seat, in the rearward longitudinal direction, applied through the seat centre of gravity by suitable rigid fixture. In its rearmost position, a force that produces a moment of 373 nm about the H-point, applied to the upper seat back, for each designated seat position. The force is applied in the rearward direction for forward facing seats, and in a forward direction for rearward facing seats. Permanent deformation or rupture of a seat belt anchorage or its surrounding areas is not considered a failure, provided the required force is sustained for the specified time. [9]

2.4 Federal Motor Vehicle Safety Standard 210 (FMVSS 210)

FMVSS 210 is for Seat Belt Assembly Anchorages — Passenger Cars, Multipurpose Passenger Vehicles, Trucks, and Buses.

2.4.1 Purpose and Scope

This standard establishes requirements for seat belt assembly anchorages to insure their proper location for effective occupant restraint and to reduce the likelihood of their failure.

2.4.2 Definition

Seat belt anchorage means any component, other than the webbing or straps, involved in transferring seat belt loads to the vehicle structure, including, but not limited to, the attachment hardware, seat frames, seat pedestals, the vehicle structure itself, and any part of the vehicle whose failure causes separation of the belt from the vehicle structure.

2.4.3 Analysis

A longitudinal force of 13345 N in the direction the seat faces, applied simultaneously to the upper torso block and the pelvic body block. The force is ramped up to its maximum value in not more than 30 sec. and held constant till 100 sec. The force application rate should not more than 13347 N/sec.[8]

3. Case Study

Toyota Yaris Sedan Passenger Vehicle driver seat model is taken from the National Crash Analysis Centre (NCAC) web. Seat is modeled and analyzed using Hypermesh and LS Dyna software's respectively as per standards recommendations. During modeling, wherever necessary seat is made fine meshed, welding of seat parts etc. are carried out.

3.1 Modal Analysis

Aim of Modal analysis is to ensure correctness of the FE Model (Welding connection check, no free parts etc). Non – structural masses such as foam, adjuster motors, electrical systems etc are not included for modal analysis. Seat is in full rear full down locked position. Head Rest assembly is not included in FE Model as it has no significance in Seat Belt Anchorage Test.

3.2 Modal Analysis Set-up

The seat is fixed at base. All translational and rotational moments are constraint at base shown in fig.2

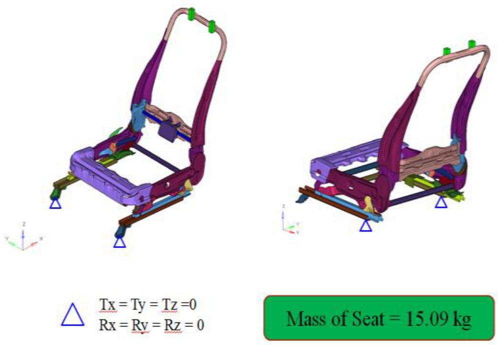

Fig.2 constrained seat

3.3 Results of Modal Analysis

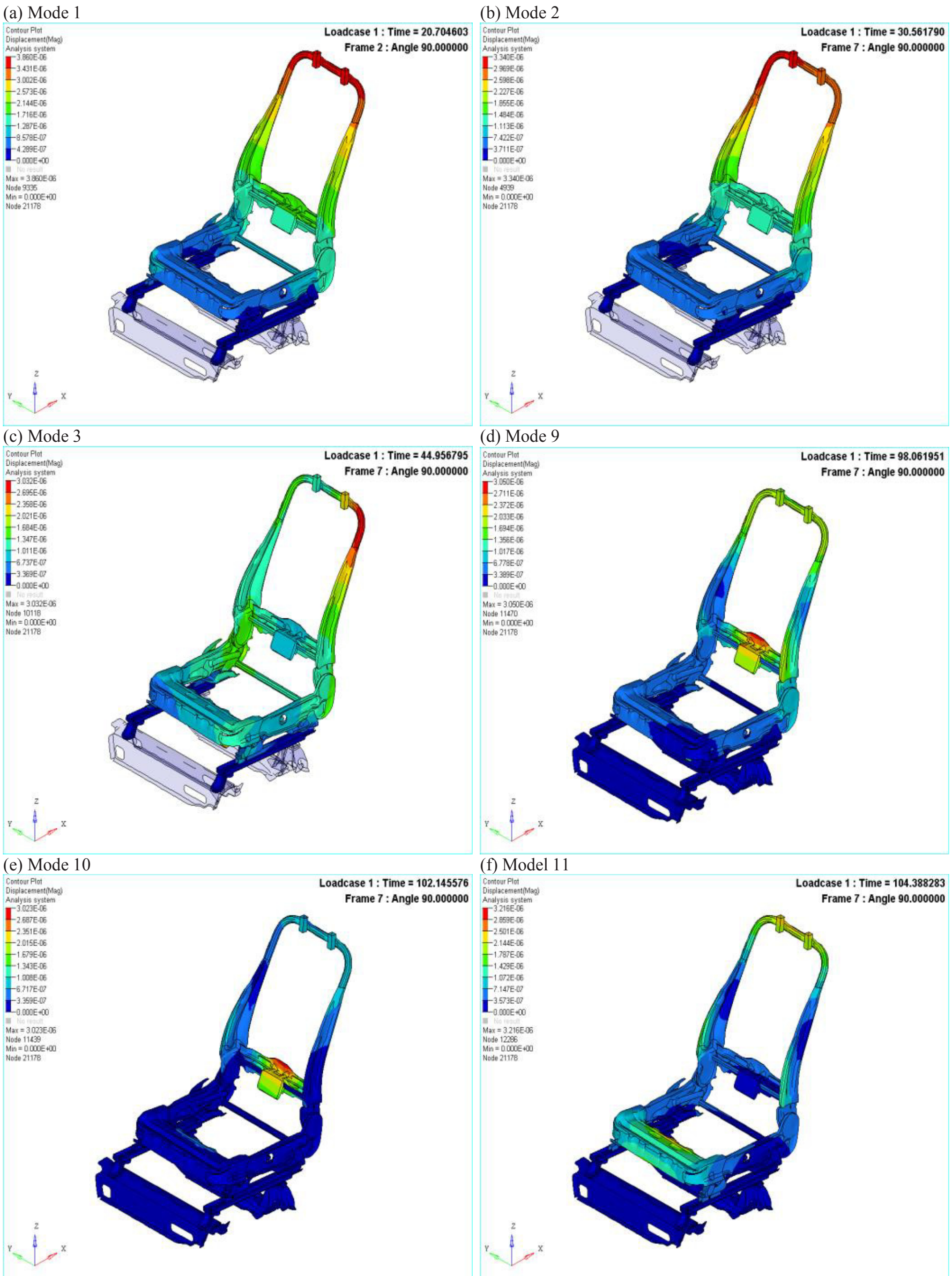

Fig. 3 Structural modes of driver seat (a) Structural,fore and aft (b) Structural,lateral (c) Structural,twist (d) Structural, backframe twist (e) Structural,mixed (f) Structural, mixed.

3.4 Result Table

Sr No.	Frequency (Hz)	Mode Shape
1	20.70	**Structural (Fore and Aft)**
2	30.56	**Structural (Lateral)**
3	44.96	**Structural (Twist)**
4	56.55	Local (Front Adjuster Bkt)
5	65.64	Local (Front Adjuster Bkt)
6	71.67	Local (Front Adjuster Bkt)
7	72.81	Local (Lower Backframe Attachment Bkt)
8	78.23	Local (Front Adjuster Bkt)
9	98.06	**Structural (Backframe Twist)**
10	102.15	**Structural (Mixed)**
11	104.39	**Structural (Mixed)**
12	126.58	Local (Cushion Pan)

Fig.4 Results of modal analysis

From the Fig.4 clearly observes the their is no connection lost between the intermediate parts of seat. First mode shape frequency (ω)is in the range of 16 to 22 Hz which indicates seat is comfortable and have strength.The seat is in condition to take seat belt analysis(S.B.A.) test.

4. Procedure of FEA seat belt assembly test

During test set up seat is in full rear full down position. All mechanisms such as adjuster Mechanism, track mechanism and reclining mechanisms are kept in locked condition. Seat back angle is maintained at design position. Shoulder block and body blocks are positioned correctly and restrained by seat belt harness. A rigid bar is welded at C.G. location on rearmost structural part of the seat. A pull chain of nearly 3m is used to apply shoulder, lap and C.G. load. A load of 13.345kN is applied on shoulder and lap block @ 5-10° to the horizontal as per FMVSS 210. A load of 20 times the total weight of seat is applied at C.G. location in horizontal direction (-ve X-direction) as per FMVSS 207. All the loads are applied simultaneously.

In Hypermesh, driver seat model is developed for Ls dyna analysis software The solver parameter are such as, remesh in coarse area, creating and defining properties and materials to components, applying constraints, defining contacts, etc. The seats cushion is modeled in 3-d elements, tetra meshing is done on cushion foam. 1-d elements are used for representation of welding joints, bolting joints, rigid. The rest seat test set up is modeled in quad and tria 2-d elements.

4.1 Seat belt analysis test set up

Assumptions made during analysis are, static foam stress- strain data of general foam has been used, Welds, bolts and riveted joints are assumed safe, Materials are Isotropic, Body in White (BIW) has been considered as rigid, Latch mechanism is not considered.

4.2 Boundary conditions

Single Surface Contacts	Surface to Surface Contacts	Xtra Node Contacts
Seat All	Seat With Foam	C.G. Bar With Seat
	Body Block With Foam	Floor with Floor Bracket Bolt
	Body Block With Seat	
	Shoulder Block With Shoulder Belt	
	Lap Block With Lap Belt	

Fig. 5 Contacts Between Model Setup

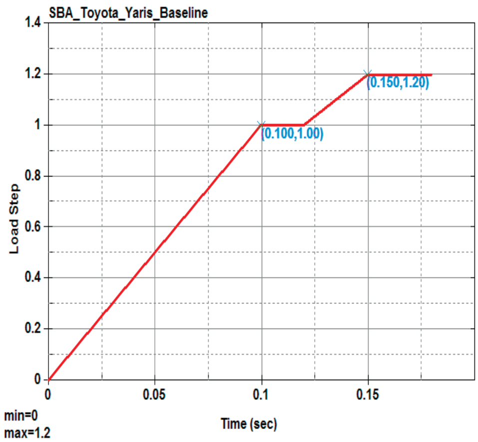

Fig. 6 Load Curve

Table 1 Input materials

SAE J2340 Material	TensileStrength (MPa)	Cold Rolled Strength (C.R.S)	Hot Rolled Strength (H.R.S.)
340 X	410	22	25
420 X	490	18	22

The Boundary condition is load curve as in standards 207/210. O.E.Ms are added 20% extra time step in load curve to ensure safety of driver as shown in Fig.6 Various inputs are also given such as thickness of various seat parts, such as track 1.5mm, bolts 10mm etc. Fig.5 distinguish the contacts in test set up. Table 1 shows the inputs contacts in model and materials respectively. The strain(ϵ) 18.5% of materials are boundary condition of that materials. Shoulder and lap belt end node is constrained because it is connected with Body In White.

4.3 Test Model

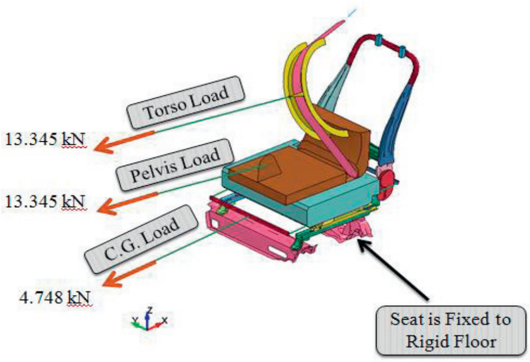

Figure 7 Driver seat test set up model

The CG of Seat is at 37.82 mm downwards from Pivot Centre & Mass of Seat is taken as 24.20 kg (Including NSM and other sub systems). Torso Load and Pelvis Load (13.345kN)are applied @ 10° to horizontal.

C.G. Load

$$F = 20 \times \text{Weight of Seat} \times 9.81$$
$$= 20 \times 24.20 \times 9.81$$
$$F = 4.748 \text{ kN applied in } -\text{ve X-direction.}$$

A force of 4748 N is applied through the centre of gravity of seat and it is ramped up to 20% over load. 13345 N load is applied individually at the lap belt and shoulder belt portion of seat structure and is ramped up to 20% over load. Failure criteria is there should not be any structural separation and catastrophic failure and no track peeling.

4.4 Results

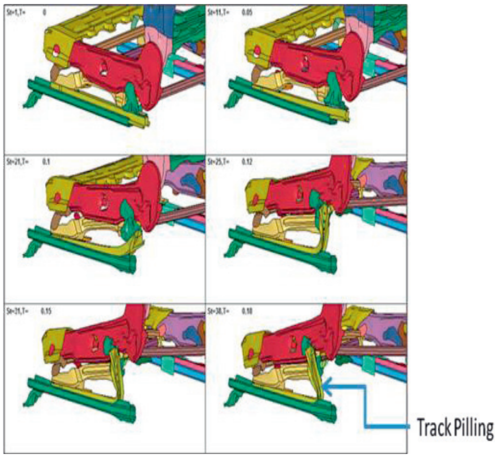

Fig 8 Animation instances

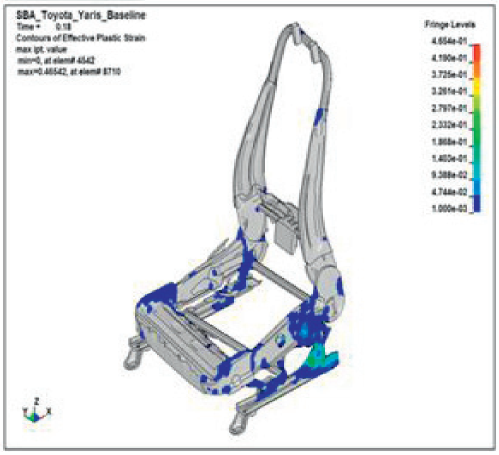

Fig 9 Strain plot

Seat does NOT meets structural integrity criteria as Upper Track IB and Lower Track IB show strains above permissible limit. Other components of concern are given for reference. Track Peeling is observed and is initiated at 0.105 sec (just after achieving 100% load). Maximum Bolt Force 10.65kN (Shear) is observed at Anchorage Bracket Front Bolt. Further strength enhancement is required in critical components such as Seat Tracks , Riser and Front Adjuster Link to withstand total load.

5. Strength Enhancement

After doing various design modifications such as increasing the track thickness, using high strength material for track or combination of both and providing additional locking J-bracket. It has been observed that providing additional J-bracket confer optimum design solution which is cost effective, easy to manufacture and assemble.

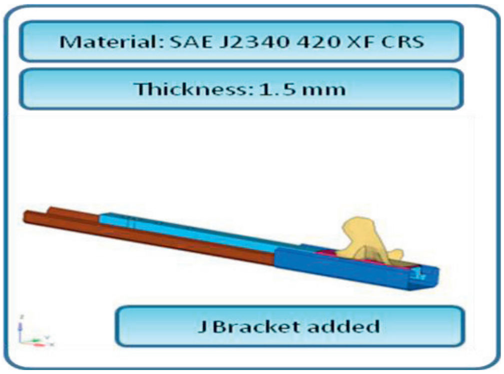

Fig.10 Track with J- Bracket

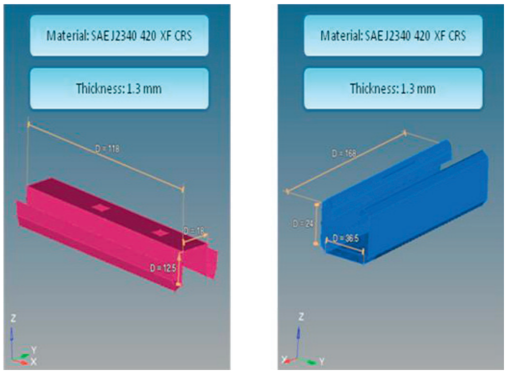

Fig. 11 Dimension of J- Bracket.

6. Result and discussion

Seat meets structural integrity criteria as strains induced in critical parts are below allowable plastic strain. Track sustains the overload, no track peeling is observed Maximum Bolt Force 16.99 kN (Axial) is observed at IB Side Rear Floor Mounting bolt. The final design of J-Bracket meets the structural integrity requirement (ensuring no track peeling shown in fig. 12 & 13). Important modifications in J-bracket design have helped to reach at final solution. A. Lower J-bracket should completely overlap Upper J-bracket. B. Proper engagement at interlocking region. C. Upper J-bracket should run throughout the upper track overhang. D. Lower J-bracket length from floor mounting location to front side should be sufficient enough to avoid rotation.

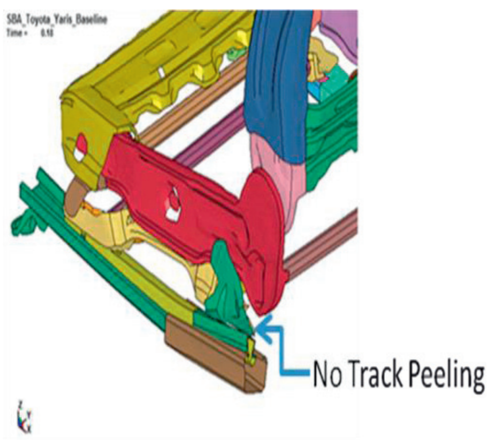

Fig 12 Animation Instance

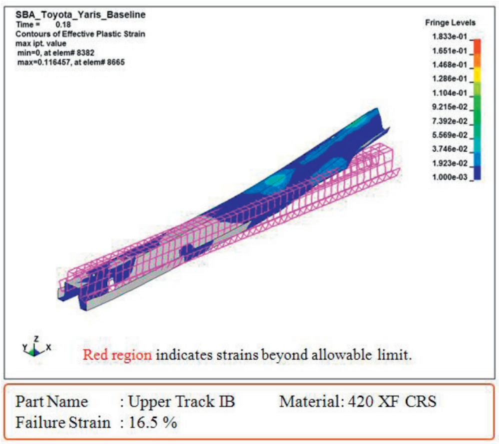

Figure 13 Strain plot of track

7. Conclusion

In the preliminary phase of vehicle design there is absence of adequate Crash Test Data, which is essential to ensure Occupant Safety. Seat Belt Anchorage Test which represents forces interacted by seat during frontal crashes is considered as one of the most important test to evaluate seat strength. In practice both Seat Belt Anchorage Test and frontal crash test (FMVSS 208) are conducted on seat (assembly level) to ensure occupant safety. But advantage of Seat Belt Anchorage Test is that it provides design guidelines for seat in absence of actual crash pulse data. Baseline design of Driver Seat does not meet SBA test requirement by showing signs of Track Peeling. Using high strength material for track or combination of both and providing additional locking J-bracket. From the above suggested design changes it has been observed that providing additional J-bracket confer optimum design solution which is cost effective, easy to manufacture and assemble. It addresses the correct nature of problem i.e. track peeling which is localized in nature and entails local treatment. Final design (with J-Bracket) meets SBA test requirements and is accepted as one of the best solutions meeting customer's needs and expectations. Solution provided has a further scope of shape optimization which can be explored further. Non-traditional design methods and materials need to be further investigated to look into potential of these methods.

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